AD-A051 395 TRACOR INC AUSTIN TEX F/G 9/3

THE EFFECT OF OR GATING IN THE AN/SQS-26(XN-2).(U)

SEP 63 H R COURTS, K L OEHLER, A F WITTENBORN NOBSR-89265

UNCLASSIFIED TRACOR-63-235-U NL

| OF |

AD
A051 395

END
DATE
FILMED
4-78
DDC

Contract NObsr-89265
Index No. SS-041-000, Task 8156
Document Number
TRACOR 63-235-U

MOST Project - 3

(1)

ADA051395

TRACOR

TECHNICAL MEMORANDUM

THE EFFECT OF OR GATING IN THE AN/SQS-26(XN-2)

Prepared for

The Bureau of Ships
Code 688E

11 September 1963

TRACOR, INC.

TRACOR, INC. 1701 Guadalupe St. Austin 1, Texas

15

Contract NObsr-89265
Index No. SS-041-000, Task 8156

14 TRACOR-63-235-U

9 TECHNICAL MEMORANDUM

6 THE EFFECT OF OR GATING IN THE AN/SQS-26 (XN-2).

Prepared for

The Bureau of Ships
Code 688E

This technical memorandum contains partial results of a series of studies performed for the SOFIX Program management.

11 11 Sep[redacted] 1963

12 16p.

Prepared by:

10 H. R. Courts

[redacted]

K. L. Oehler

[redacted]

A. F. Wittenborn

A. F. Wittenborn

TABLE OF CONTENTS

The Effect of OR Gating in the AN/SQS-26(XN-2)

I. INTRODUCTION

The purpose of this technical note is to describe the effect of using an OR gate to combine several channels of data. It is shown that the OR gate system is equivalent to a multiple channel system having an operator to observe each of the multiple channels simultaneously if the total false alarm rate is the same for each system. This does not preclude a loss in signal-to-noise ratio when the OR gate system is compared to only one channel of a multiple channel system, but this loss occurs because the single channel covers only a fraction of the signal-and-noise space covered by the OR gate system. For convenience this loss is often referred to as "OR gate loss," although it should be realized that the underlying cause of the loss is the extended coverage of the OR gate system. An empirical equation for this loss in signal-to-noise ratio is developed from the results of a digital computer simulation of the OR gate system using recorded sea-test data. This empirical result is used to compare a single-channel system to a similiar system in which the single channel is divided into multiple channels so as to improve the filtering, after which the channels are recombined through an OR gate. It is shown that the multiple-channel system is superior to a single-channel system in the region of interest, even though the single-channel system tends to be better in the region of very small signal-to-noise ratios.

II. PROBLEM DISCUSSION

In general the purpose of OR gating is to select the best output from several channels of data. It is known that information is lost in any process which reduces several channels, each with bandwidth B, to a single channel with bandwidth B. In the application of OR gating to be considered in this note, the several input channels to the OR gates are obtained from the rectified and averaged outputs of a bank of doppler filters. The filter output with the largest magnitude is defined to be the best output.

At this point one can consider whether or not it is desirable to use an averaging time sufficiently long to reduce the bandwidth of the difference frequency band. In general, if the doppler filter used is a matched filter for the signals being received, then optimum linear processing is performed and further bandlimiting can yield no further processing gain. However, if the doppler filter bandwidth is wider than the bandwidth of the signals being received, further processing gain can be obtained by using an averaging time which reduces the bandwidth to the minimum required to pass the signal shape. It will be shown later that the loss in signal-to-noise ratio incurred by combining several channels of data increases as the input signal-to-noise ratio decreases. For this reason, if additional bandlimiting is required it should be performed before the OR gating to minimize the loss in signal detectability.

III. DESCRIPTION OF THE SIMULATION OF THE OR GATES

Let $x_p(t)$ be the detected output of the p'th doppler filter at time (t). Let $Y_N(t)$ be the output of the OR gates with N channels of input. Then

$$Y_1(t) = X_1(t)$$

$$Y_2(t) = \frac{|Y_1(t) - x_2(t)| + |Y_1(t) + x_2(t)|}{2}$$

$$Y_3(t) = \frac{|Y_2(t) - x_3(t)| + |Y_2(t) + x_3(t)|}{2}$$

$$Y_N(t) = \frac{|Y_{N-1}(t) - x_N(t)| + |Y_{N-1}(t) + x_N(t)|}{2}$$

In the simulation of the OR gates it was assumed that all of the OR inputs are described by the same statistics and are statistically independent in the absence of signal. The set of OR inputs used in the simulation was obtained by correlating 15 listening periods of data recorded on the AN/SQS-26(XN-2). The system was operating in the bottom bounce mode, 20 degree depression angle, FM signals, with no target. The data were recorded at the input to the clipper amplifier. This set of data was used to include any effects which may be due to reverberation. The cumulative probability function of the correlator output for a typical reception period is shown in Figure 1. A Gaussian distribution with the same mean and variance is also shown for comparison. Band-limited Gaussian noise has also been correlated and the cumulative probability function of the correlator output is essentially the same as that with reverberation input. Note that for large values of x the Gaussian curve is much closer to 1 than cumulative probability of the correlator output. This means that large correlator outputs resembling signals are more likely to occur than would be the case if the correlator output were Gaussian.

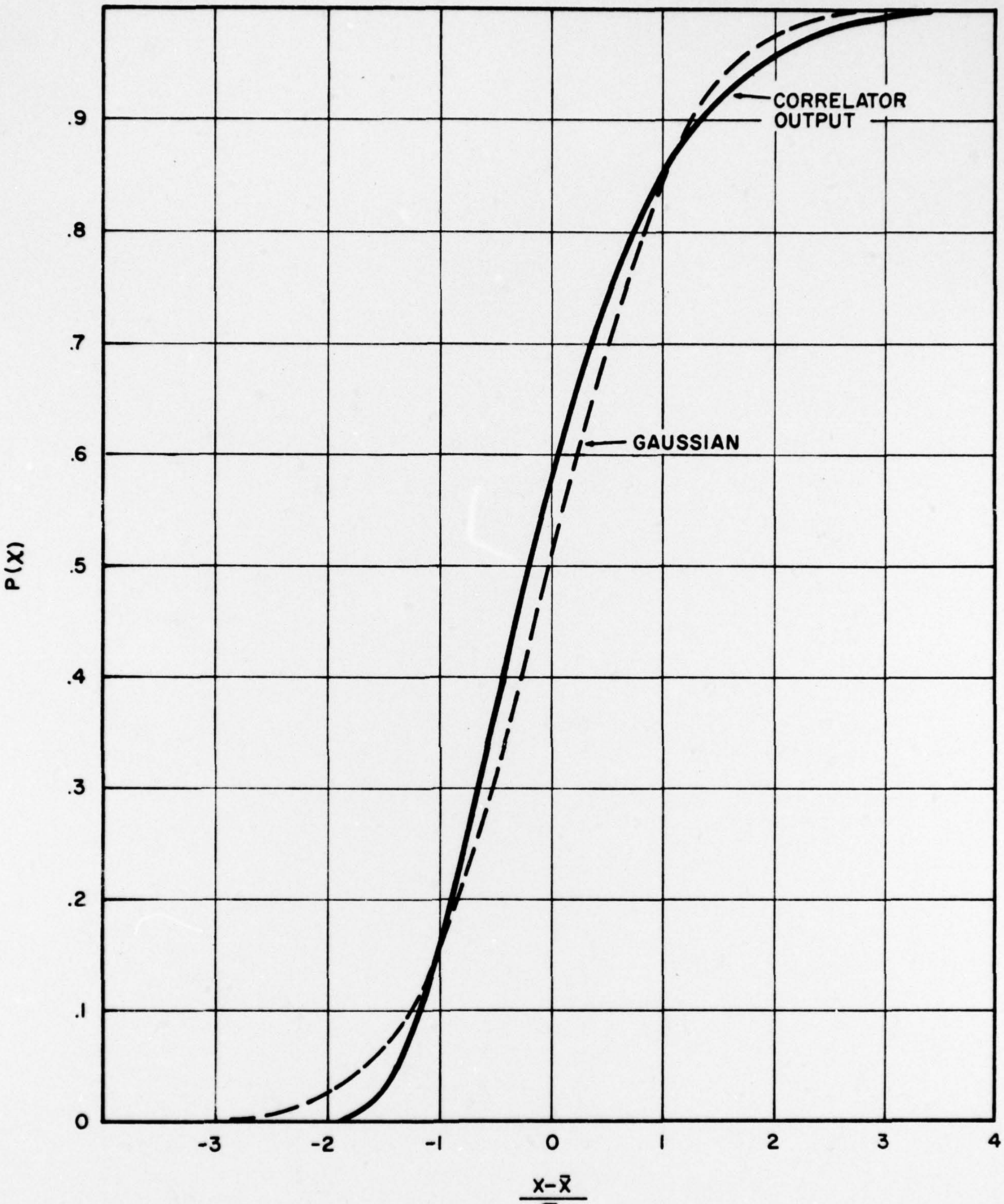

Fig. 1 – CUMLATIVE PROBABILITY, P(X), OF A TYPICAL CORRELATOR OUTPUT

TRACOR, INC.	DWG. A742-28	
AUSTIN, TEXAS	9-19-63	KLO-CB

IV. INTERPRETATION OF THE RESULTS OBTAINED

Using the sets of data described in the previous section, the OR gates were simulated varying the number of OR gate inputs from 2 to 15. Table 1 shows the mean, change in the mean and standard deviation obtained as the number of OR inputs increases.

The experimental data tabulated in Table 1 are adequately described by the following empirical equations. The mean of the OR circuit output is given by

$$\overline{Y}_N \approx \overline{Y}_1 + 0.55\, \sigma_1 \sqrt{N-1} \tag{1}$$

where

$\overline{Y}_N$ = the mean of the output of an OR gate with N input channels

$\overline{Y}_1$ = the mean of one OR gate input

σ_1 = the standard deviation of one OR gate input

N = the number of OR gate inputs.

Similarly the standard deviation of the OR gate output is represented by

$$\sigma_N \approx \sigma_1 \left(1 - 0.0653 \sqrt{N-1}\,\right) \tag{2}$$

where

σ_N = the standard deviation of the output of an OR gate with N input channels

σ_1 = the standard deviation of one OR gate input

N = the number of OR gate inputs.

TABLE I

N Number of input channels	$\overline{Y}_N$ Mean of OR gate output	$\Delta\overline{Y} = \overline{Y}_N - \overline{Y}_1$ Change in output mean	σ_N Standard deviation of OR gate output	$\overline{Y}_N/\overline{Y}_1$ Normalized output mean
1	.06626	.0	.02993	1.00
2	.08277	.01651	.02906	1.25
3	.09209	.02583	.02791	1.39
4	.09861	.03235	.02666	1.49
5	.10338	.03712	.02614	1.56
6	.10696	.04070	.02541	1.62
7	.10995	.04369	.02460	1.66
8	.11258	.04632	.02442	1.70
9	.11503	.04877	.02411	1.74
10	.11750	.05124	.02357	1.77
11	.11947	.05321	.02327	1.80
12	.12122	.05496	.02315	1.83
13	.12306	.05680	.02288	1.86
14	.12442	.05816	.02278	1.88
15	.12544	.05918	.02244	1.90

Noting that the amplitude of a signal spike at the output of an OR gate is identical to the amplitude at the input, it is seen that a change in signal-to-noise ratio is due to the change in the mean and standard deviation. The signal-to-noise ratio of one of the input channels is defined by

$$(S/N)_{IN} = \frac{(S-\overline{Y}_1)^2}{\sigma_1^{\,2}} \tag{3}$$

where S is the amplitude of the signal peak. Similarly the OR gate output signal-to-noise ratio is defined by

$$(S/N)_{OUT} = \frac{(S-\overline{Y}_N)^2}{\sigma_N^{\,2}} \quad . \tag{4}$$

The loss in signal-to-noise ratio is then determined by

$$S/N\ \text{Loss}_{db} = 10 \log_{10} \frac{(S/N)_{IN}}{(S/N)_{OUT}} \quad . \tag{5}$$

Substituting Equations (3) and (4) into (5) yields

$$S/N\ \text{Loss}_{db} = 20 \log_{10} \left[\frac{\sigma_N \ (S-\overline{Y}_1)}{\sigma_1 \ (S-\overline{Y}_N)} \right] \quad . \tag{6}$$

Using Equations (1) and (2) one obtains from Equation (6)

$$S/N\ \text{Loss}_{db} = 20 \log_{10} \left[\frac{(S-\overline{Y}_1)}{\sigma_1} \ \frac{(1 - 0.0653\sqrt{N-1}\ )}{\left(\frac{(S-\overline{Y}_1)}{\sigma_1} - 0.55\sqrt{N-1}\ \right)} \right] \quad . \tag{7}$$

The dependence of the signal-to-noise loss upon the input signal-to-noise ratio is more obvious if Equation (7) is rewritten as

$$\text{S/N Loss} = 20 \log_{10} \left[\frac{\sqrt{(S/N)_{IN}} \quad (1 - 0.0653 \sqrt{N-1}\,)}{\sqrt{(S/N)_{IN}} \quad - 0.55 \sqrt{N-1}} \right] . \qquad (7a)$$

Figure 2 is a plot of the signal-to-noise ratio loss as a function of input signal-to-noise ratio with the number of channels treated as a parameter. The tendency toward zero loss for large input signal-to-noise ratios is due to the decrease in the standard deviation. In interpreting the signal-to-noise ratio loss shown in Figure 2, it must be kept in mind that the OR gate system is not being compared to a complete system of equivalent coverage, but the OR gate system is being compared to only one of the input channels.

Consider now a possible alternative to the 15 channel OR gate system used for doppler processing in the AN/SQS-26(XN-2). It could be argued that the 15 channels are not necessary because processing gains made by separating the data into 15 channels are lost when the channels are recombined with an OR gate. Analysis shows that this reasoning is valid in the case of very small signal-to-noise ratios, but that the multiple channel is superior in the more practical cases where the output signal-to-noise ratio is greater than 5 db.

The effect of dividing the signal channel by using various numbers of doppler filters is illustrated in Figure 3. Here the OR gate output signal-to-noise ratio is plotted as a function of the signal-to-noise ratio at the input to the correlator. Allowance is made for a possible doppler shift of ±15 cps, and a pulse of 100 cps bandwidth and 0.5 sec duration is assumed. For the case of

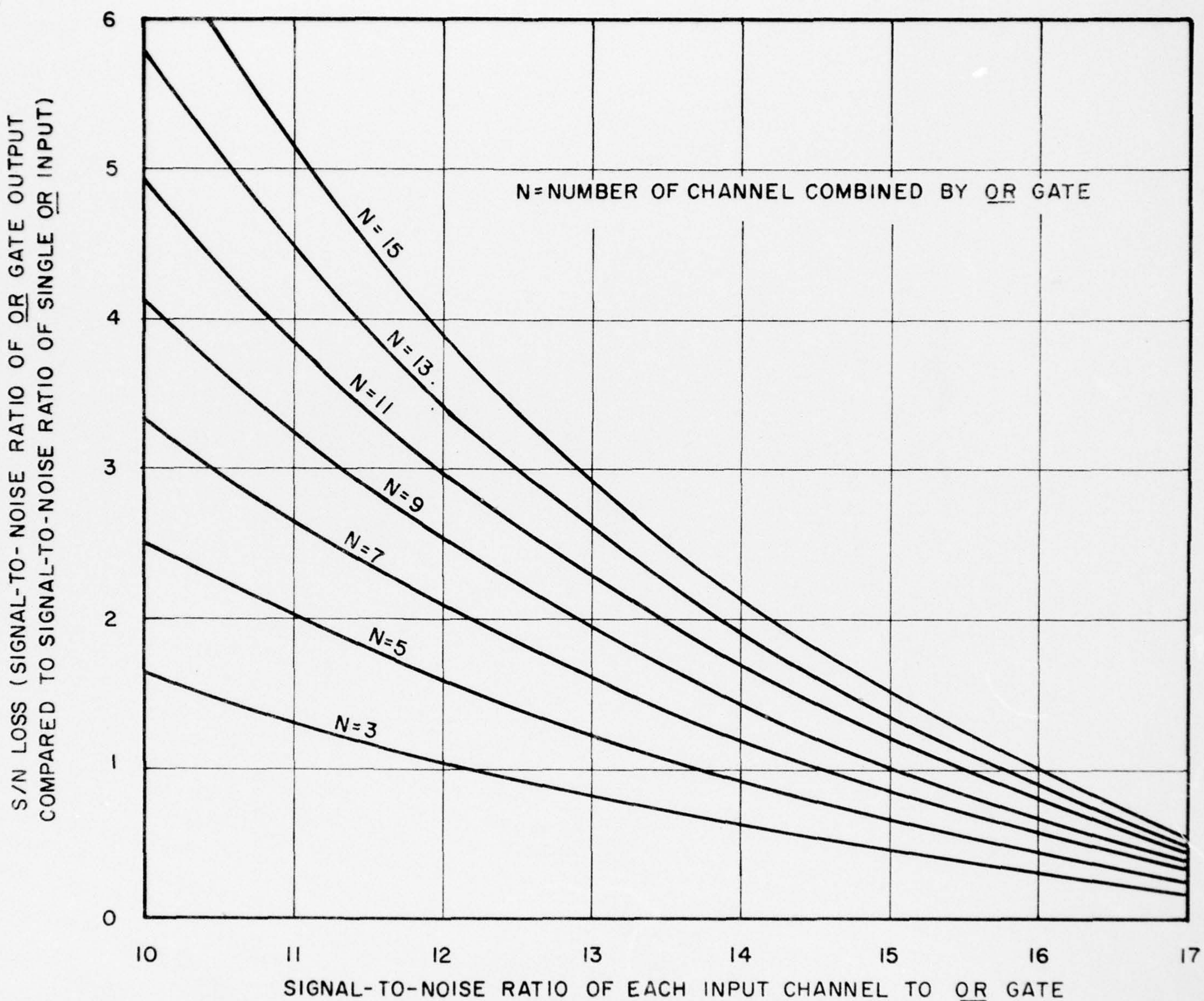

Fig. 2-OR GATE LOSS

TRACOR, INC. DWG. A742-29
AUSTIN, TEXAS 9-19-63 KLO-CB

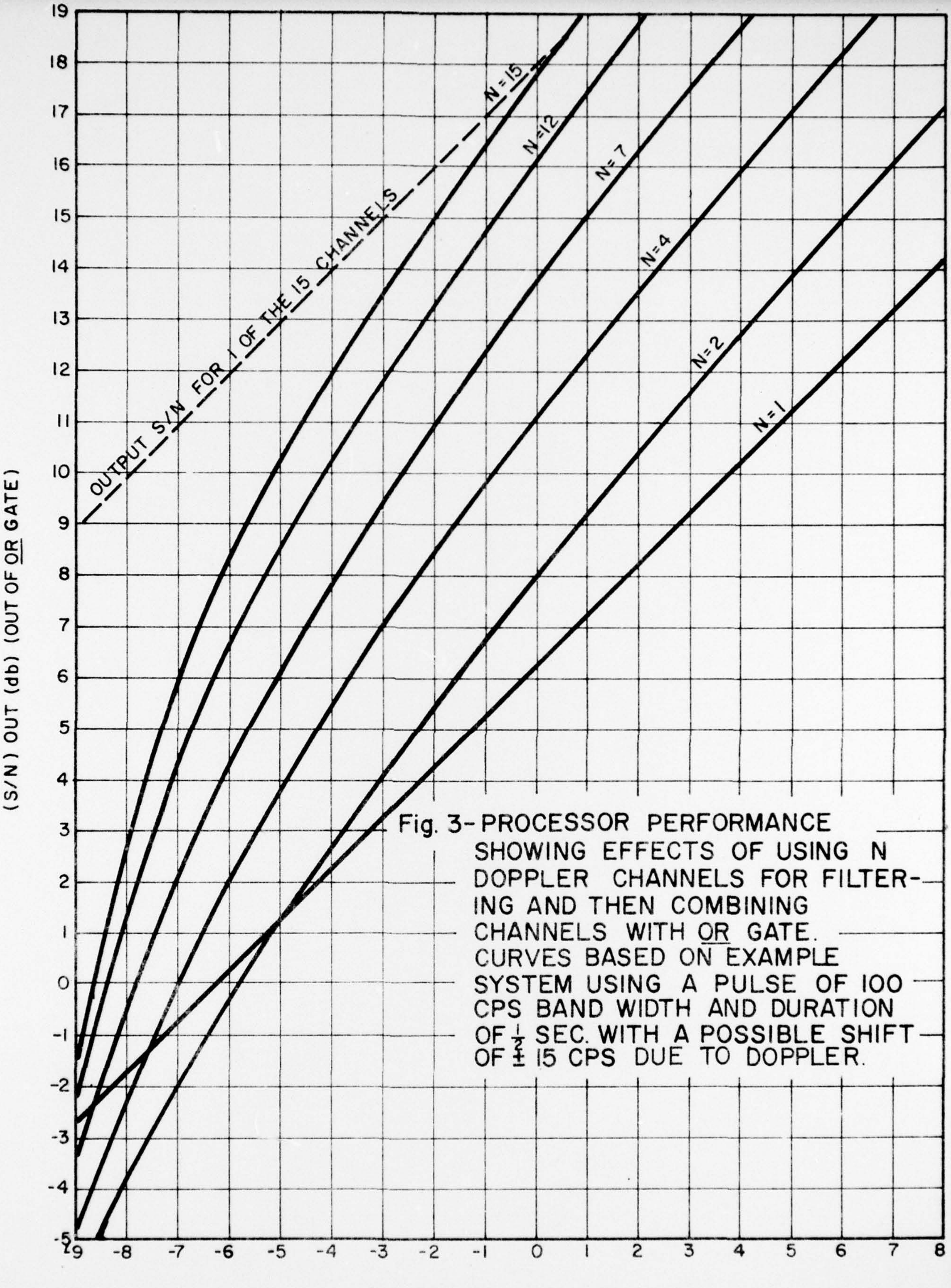

Fig. 3- PROCESSOR PERFORMANCE SHOWING EFFECTS OF USING N DOPPLER CHANNELS FOR FILTERING AND THEN COMBINING CHANNELS WITH OR GATE. CURVES BASED ON EXAMPLE SYSTEM USING A PULSE OF 100 CPS BAND WIDTH AND DURATION OF $\frac{1}{2}$ SEC. WITH A POSSIBLE SHIFT OF $\pm$ 15 CPS DUE TO DOPPLER.

TRACOR, INC.	DWG A742-30
AUSTIN, TEXAS 9-19-63	KLO-CB

N=1, the hypothetical system uses only one doppler filter 30 cps wide; for the case of N=2, the system uses 2 doppler filters, each 15 cps wide; etc.; and for the case of N=15, the system uses 15 doppler filters, each 2 cps wide. Figure 3 clearly illustrates the superior performance of the multiple channel system at higher signal-to-noise ratios and also shows that the single channel system tends to have the better performance at very low signal-to-noise ratios.

It is also instructive to compare the OR gated system to an equivalent multiple channel system having an operator to simultaneously observe the output of each individual channel. The operator observing the N simultaneous channels would be required to establish a threshold for each channel such that the total false alarm rate could be established at the acceptable level. Note that this threshold is higher than would be required if one were only interested in the contents of one channel since each channel contributes only a fraction, $\frac{1}{N}$, of the total false alarm rate. Now consider the output of the OR gate system for which the same threshold is established. (The threshold being measured by the absolute value of the threshold above zero.) Each false alarm signal which exceeded the threshold in its own channel will also exceed the same threshold at the output of the OR gate. Similarly, no signal which does not exceed the threshold in its own channel will cause the OR gate threshold to be exceeded. Hence the OR gate system will have the same false alarm rate as does the multiple channel system. The OR gate has a similar effect on signal detectability. If any signal exceeds the threshold in its own channel, it would also exceed the same threshold at the OR gate output and hence there is no loss in signal detectability if the threshold concept is used.

V. EXAMPLE

To obtain an example of the effect of the OR gates, an echo listening cycle which contains two echoes was correlated. The correlator output containing the echoes is shown as the top graph in Figure 4. This correlator output was then OR gated with other correlator outputs which contained no echoes. The results obtained with N = 3, 5, 7, 9, 11, 13 and 15 are shown in Figure 4. The values of the mean and standard deviation listed in Table 1 are applicable to the graphs in Figure 4. The signal-to-noise ratio of the first and second signal for N = 1 are 14.7 db and 13.4 db respectively. From Figure 2 the loss should be 1.7 db and 2.6 db respectively with N = 15, so that at the output of the OR gate the signal-to-noise ratio is 13.0 db and 10.8 db respectively. Note that the 10.8 db signal is exceeded by several noise spikes at the OR gate output; however these same noise spikes would have exceeded the threshold in their own channels if the thresholds of a multiple channel system were set low enough to detect the 13.4 db signal.

> NOTE: The authors of this memorandum are familiar with a closely related paper by H. R. Eady, _et al_, of the Navy Electronics Laboratory. Because the authors do not have immediate access to the earlier paper, this memorandum is issued without the complete reference which is properly due to H. R. Eady, _et al_, in the interest of expediency.

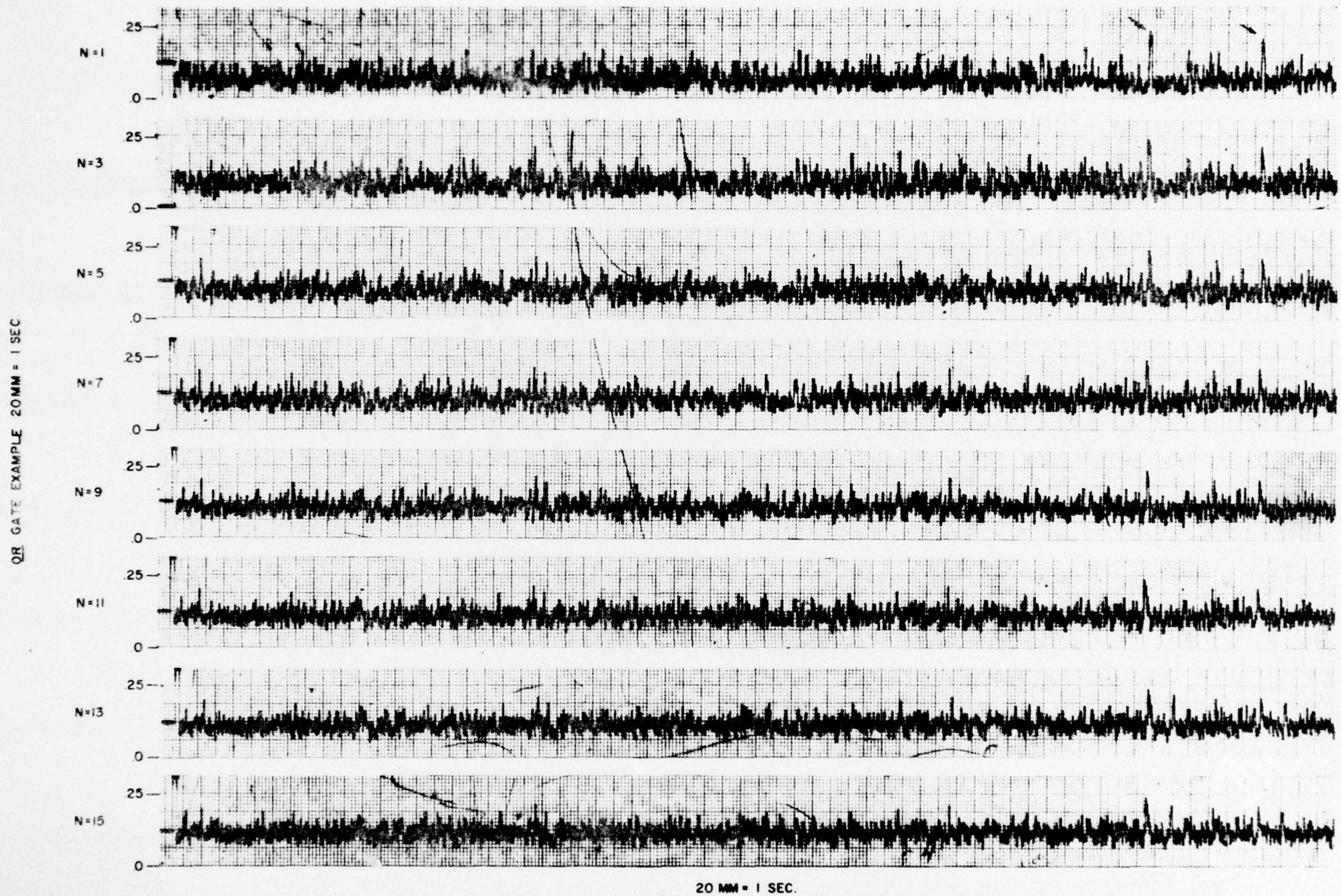

Fig. 4—TYPICAL OR GATE OUTPUTS FOR VARIOUS NUMBERS OF INPUT CHANNELS. (TWO SIGNALS ARE SHOWN IN CHANNEL 1).

TRACOR, INC. AUSTIN, TEXAS DWG. B742-31